AD-A063 909 ARINC RESEARCH CORP ANNAPOLIS MD F/G 13/10
MAINTENANCE-HISTORY ANALYSIS OF MAIN FEED PUMP TURBINES FOR DDG--ETC(U)
FEB 73 M DUNCAN N00140-73-D-0074
UNCLASSIFIED 1012-01-2-1231 NL

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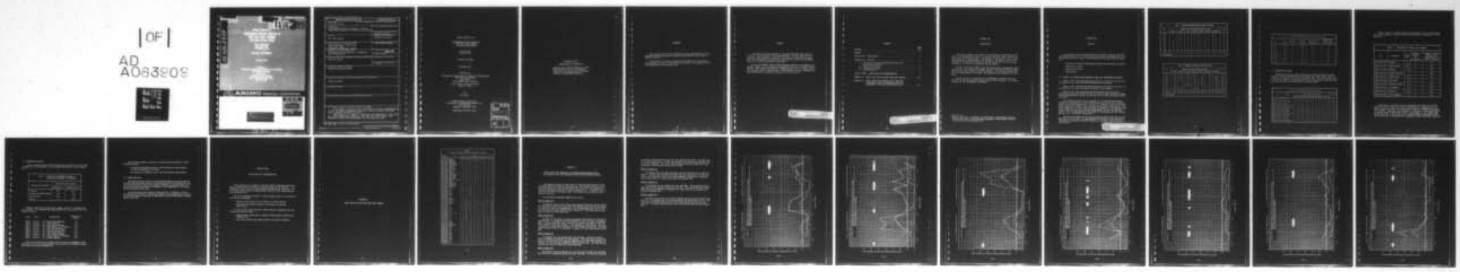

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Publication 1812-01-2-1231

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SPECIAL REPORT NO. [illegible]

MAINTENANCE-HISTORY ANALYSIS OF MAIN FEED PUMP TURBINES FOR DDG-2 CLASS SHIPS

EICs F803300
Z013000 (Old)

CID/APL 057300044

February 1973

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
(ANTI-AIRCRAFT WARFARE)
PERA (AAW)
PHILADELPHIA NAVAL SHIPYARD
[illegible]-73-C-[illegible]
[illegible] No. [illegible]

ARINC RESEARCH CORPORATION

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DISTRIBUTION STATEMENT A
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79 01 16 142

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER
1012-01-2-1231

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Maintenance-History Analysis of Main Feed Pump Turbines for DDG-2 Class Ships

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER
1012-01-2-1231

7. AUTHOR(s)
Mr. Max Duncan

8. CONTRACT OR GRANT NUMBER(s)
N00140-73-D-0074

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Arinc Research Corporation
2551 Riva Road
Annapolis, Maryland 21401

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Planning and Engineering for Repairs and Alterations

12. REPORT DATE
Feb 73

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
same as above

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
UNCLASSIFIED-UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
same as above

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is one of four selected as being representative of the equipment maintenance-history analyses being preformed under Contract N00140-73-D-0074.

Approimately 50 reports, covering 75 equipments in the 1200-psi steam propulsion plant for DLG and DDG class ships, were prepared during the preformance of the contract work.

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SPECIAL REPORT NO. 6

MAINTENANCE-HISTORY ANALYSIS OF MAIN FEED PUMP TURBINES FOR DDG-2 CLASS SHIPS

EICs F303300
ZQ13000 (Old)

CID/APL 057300044

February 1973

Prepared for
Planning and Engineering for Repairs and Alterations
(Anti-Aircraft Warfare)
PERA (AAW)
Philadelphia Naval Shipyard

under Contract N00140-73-D-0074
Order No. T0002

by

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Publication 1012-01-2-1231

FOREWORD

This report is one of four selected as being representative of the equipment maintenance-history analyses being performed under Contract N00140-73-D-0074.

Approximately 50 reports, covering 75 equipments in the 1200-psi steam propulsion plant for DLG and DDG class ships, were prepared during the performance of the contract work.

SUMMARY

A maintenance-history analysis of the Main Feed Pump (MFP) turbines in seven ships of the DDG-2 class was conducted. Factors taken into consideration were frequency of corrective maintenance, repair-parts usage, type and seriousness of malfunctions, and trends in corrective-maintenance events and corrective-maintenance man-hours.

For the USS TOWERS (DDG-9), ARINC Research Corporation recommends that the MFP turbines not be completely overhauled during the forthcoming Regular Overhaul (ROH) unless some specific malfunction has recently occurred that would warrant special consideration. ARINC Research further recommends that steam glands and air glands be replaced in all MFP turbines.

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CHAPTER ONE

INTRODUCTION

This report presents the results of an analysis of available data related to the maintenance history of the main feed pump (MFP) turbines for seven ships of the DDG-2 class. The purpose of the analysis was to determine appropriate recommendations for overhaul. The approach used in the analysis is the same as discussed in Special Report No. 1*; for the sake of brevity, it will not be described in this report.

The main feed pump turbine is of the single-stage, horizontally split-casing type. The six main feed pumps (three in each main machinery space) are turbine-driven through a flexible coupling. The turbine delivers 580 bhp at a rated speed of 7,480 rpm. The operating steam pressure is 1,050 psig.

The MFP turbine is identified by the Equipment Identification Code F303300 and has the Component Identification (CID) 057300044. It is manufactured by the Worthington Corporation.

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*Special Report No. 1, *Approach for Development of Maintenance History Analysis for DDG-2 Class Propulsion Equipments*, ARINC Research Publication 1012-01-1-1230, February 1973.

CHAPTER TWO

ANALYSIS

A maintenance history was developed for the MFP turbine by combining and analyzing MDCS data, shipyard data and information, CASREPT data, and information from ship visits. The following are the major areas of analysis:

- History of Corrective-Maintenance Events and Maintenance Man-Hours
- Repair-Parts Usage
- Malfunction History
- Trend Curves

2.1 HISTORY OF CORRECTIVE-MAINTENANCE EVENTS AND MAINTENANCE MAN-HOURS

Table 1 lists corrective-maintenance events, by year and by ship, for all ships for the total time period covered by the analysis.

Table 2 lists reported maintenance man-hours, by year and by ship, for all ships for the total time period covered by the analysis.

Table 3 lists the average maintenance man-hours per corrective-maintenance event and the average time (in turbine operating hours) between corrective-maintenance events, by ship and for all ships, during the analysis period.

This analysis reveals that an average of 53 corrective-maintenance actions were conducted on the MFP turbines on each ship during the period covered by the maintenance data. For the six turbines in each of the seven ships, operating a total of 340,831 hours during the six-year period, this is an average of one event every 916 hours of operation. The reported maintenance man-hours per ship averaged approximately 460 for the six-year period. This is approximately 13 man-hours of maintenance per MFP turbine per year for 1,350 hours of operation.

This analysis shows that the corrective-maintenance experience on the MFP turbines in the DDG-9 is approximately the average of the corrective-maintenance experience on the MFP turbines in the seven ships included in the analysis.

Table 1. CORRECTIVE-MAINTENANCE EVENTS, MAIN FEED PUMP TURBINE

Year	Number of Corrective-Maintenance Events, by Ship							Totals
	DDG-4	DDG-5	DDG-6	DDG-9	DDG-14	DDG-23	DDG-24	
1966 *	3	1	3	19	1	8	2	37
1967	3	14	11	5	1	8	17	59
1968	3	14	18	16	5	2	9	67
1969	23	12	3	4	10	9	13	74
1970	10	4	10	3	5	5	10	47
1971	12	16	17	7	3	8	7	70
1972 *	4	4	0	3	0	1	6	18
Totals	58	65	62	57	25	41	64	372

*One-half year.

Table 2. MAINTENANCE MAN-HOURS, MAIN FEED PUMP TURBINE

Year	Number of Maintenance Man-Hours, by Ship							Totals
	DDG-4	DDG-5	DDG-6	DDG-9	DDG-14	DDG-23	DDG-24	
1966 *	24.0	72.5	18.0	210.1	0	59.9	1.6	386.1
1967	95.5	422.2	23.8	48.0	18.0	25.0	288.2	920.7
1968	6.0	78.7	105.7	175.0	17.6	.8	110.5	494.3
1969	93.5	8.5	2.0	40.0	43.6	6.5	134.2	328.3
1970	5.3	0	145.6	10.0	16.3	1.2	55.0	233.4
1971	144.6	55.6	419.3	6.0	4.6	26.9	91.2	748.4
1972 *	21.5	49.5	0	15.0	0	0	18.5	104.9
Totals	390.4	687.6	714.4	504.1	100.1	120.3	699.2	3,216.1

*One-half year.

Table 3. CORRECTIVE-MAINTENANCE-EVENT RATES, MAIN FEED PUMP TURBINE

Ship	Operating Hours	Corrective-Maintenance Events	Corrective-Maintenance Man-Hours	Average Maintenance Man-Hours per Maintenance Event	Average Turbine Operating Hours Between Corrective-Maintenance Events
DDG-4	45,864	58	390.4	6.7	791
DDG-5	44,277	65	687.6	10.6	681
DDG-6	51,333	62	714.4	11.5	828
DDG-9	42,492	57	504.1	8.8	745
DDG-14	52,596	25	100.1	4.0	2,104
DDG-23	49,415	41	120.3	2.9	1,205
DDG-24	54,854	64	699.2	10.9	857
All Ships	340,831	372	3,216.1	8.6	916

2.2 REPAIR-PARTS USAGE

Appendix A lists all parts reported to have been used by the seven ships for the MFP turbines during the period July 1966 through June 1972. A total of 93 different FSNs were reportedly used. The list of parts was reviewed, and Table 4 was developed to list all major parts used more than once by more than one ship during the six-year period.

Table 4. PARTS USAGE, MFP TURBINE (Major Parts Only)

FSN	Noun Name	Number of Parts Used, by Ship							All Ships
		DDG-4	DDG-5	DDG-6	DDG-9	DDG-14	DDG-23	DDG-24	
2010 300 4578	Bearing	4	1	4	1	1	0	0	11
2010 343 7377	Thrust Shoes	45	53	24	40	12	18	8	200
2010 629 6943	Bearing	3	5	2	2	2	0	4	18
2825 509 6310	Turbine Bellows	5	0	0	3	1	0	0	9
2825 509 6311	Steam Gland	7	10	4	7	6	14	0	48
2825 509 6312	Air Gland	6	10	5	8	6	6	0	41
2825 509 6314	Governor Valve	6	2	0	2	0	0	0	10
2825 509 6322	Oil Baffle	7	2	0	2	1	0	7	19
2825 509 6332	Bearing	4	2	5	4	1	1	1	18
4320 544 6940	Ring Assembly	0	1	6	2	0	0	0	9

Table 5 shows the interval between replacements of major repair parts for the MFP turbines, estimated by using the procedure presented in Special Report No. 1.

Table 5. PERIODICITY OF PARTS, MFP TURBINES

FSN	Noun Name	Total Used	Average Quantity Per Occurrence	Estimated Interval Between Parts Replacements Per Turbine (Months)
2010 300 4578	Bearing	11	1	275
2010 343 7377	Thrust Shoes	200	8	120
2010 629 6943	Bearing	18	1	168
2825 509 6310	Turbine Bellows	9	1	336
2825 509 6311	Steam Gland	48	1	63
2825 509 6312	Air Gland	41	1	74
2825 509 6314	Governor Valve	10	1	302
2825 509 6322	Oil Baffle	19	2	318
2825 509 6332	Bearing	18	1	168
4320 544 6940	Ring Assembly	9	1	336

From Table 5, the most critical frequencies are those of the steam gland and the air gland, for which the periodicity is approximately 1.8 and 2.1 operating intervals, respectively, based on an operating interval of 36 months. Therefore, the probability of failure of these parts before or shortly after a second ROH is high if replacement is not accomplished during every ROH. Other parts have a higher estimated replacement interval and need not be considered for replacement sooner than every other ROH.

2.3 MALFUNCTION HISTORY

Table 6 categorizes MFP turbine malfunctions reported from July 1966 through June 1972 according to the procedure described in Special Report No. 1.

Table 6. PERCENT OF MAINTENANCE EVENTS BY MALFUNCTION CATEGORY, MFP TURBINE

Malfunction Category	Percent of Total Events	
	Generation I	Generation III
Wearout	62.7	61.8
Operational/Environment	20.6	4.2
Maintenance	13.5	7.4
Other	3.2	26.6

CASREPT summaries for the period 1 January 1970 to 31 December 1972 were analyzed. Ten CASREPTS were submitted by the seven ships on MFP turbines as follows:

Ship	Date	Malfunction	Malfunction Impact
DDG-4	4-7-70	1B - Worn Thrust Bearing	C-2
DDG-5	9-29-70	2C - Gasket Failed	C-2
DDG-4	11-10-70	2A - Worn Thrust Bearing	C-2
DDG-4	12-1-70	2A - Worn Bearing & Oil Baffle	C-2
DDG-5	2-24-71	2A - Worn Thrust Bearing	C-2
DDG-4	5-25-71	2B - Sheared Turbine Shaft	C-2
DDG-6	6-15-71	2A - Worn Thrust Bearing	C-2
DDG-5	10-14-71	2A - Worn Journal Bearing	C-2
DDG-6	5-24-72	1B - Broken Blades & Shrouding	C-2
DDG-5	8-20-72	2A - Broken Governor	C-2

Four of the seven ships analyzed did not submit any CASREPTs on MFP turbines during the three-year period, and six of the ten CASREPTs showed worn parts as the basic malfunction.

The following general conclusions are made from the analysis of malfunction history:

- Corrective-maintenance events on MFP turbines are wear-related at least 60 percent of the time.
- The majority of CASREPTs result from wear-related malfunctions.

2.4 TREND ANALYSIS

Maintenance-trend curves of corrective-maintenance events per operating hour and maintenance man-hours per operating hour were plotted for each of the seven ships by using the procedure presented in Special Report No. 1. The trend curves are presented in Appendix B with summaries of the circumstances associated with them.

The maintenance-trend analysis indicated that, in general, the lack of shipyard work caused no significant changes in the maintenance rates and that the maintenance trends do not establish a need for MFP turbine overhaul during every ROH.

CHAPTER THREE

CONCLUSIONS AND RECOMMENDATIONS

Steam glands and air glands in the MFP turbine exhibited significant wearout characteristics during the period covered in this analysis. Replacement of steam and air glands should be scheduled for every ROH. All other major parts should be replaced upon failure or upon identification of significant wear.

For the forthcoming overhaul of the USS TOWERS (DDG-9), the following actions are recommended:

- Replace steam glands and air glands in all MFP turbines
- Make other MFP turbine repairs on the basis of reported deficiencies

For DDG-2 class ships generally, ARINC Research recommends that the following actions be taken:

- Replace steam glands and air glands in MFP turbines during every scheduled ROH
- Make other repairs upon identification of specific problems

APPENDIX A

PARTS USAGE DATA FOR MAIN FEED PUMP TURBINE

APPENDIX A

PARTS USAGE DATA FOR MAIN FEED PUMP TURBINE, JULY 1966 TO JUNE 1972 (CID 057300044)

Federal Stock Number	Part Name	Ship							Total
		DDG-4	DDG-5	DDG-6	DDG-9	DDG-14	DDG-23	DDG-24	
2010 300 4578	Bearing	4	1	1	1	1	0	0	11
2010 343 7377	Thrust Shoes	45	53	24	40	12	18	8	200
2010 629 6943	Bearing	3	5	2	2	2	0	4	18
2825 132 5108	Thrust Bearing	1	0	0	1	0	0	0	2
2825 313 9831	Rotor-Turbine	1	0	0	0	0	0	0	1
2825 509 6309	Bellows - Turbine	0	0	0	1	0	0	0	1
2825 509 6310	Bellows - Turbine	5	0	0	3	1	0	0	9
2825 550 6311	Gland - STM	7	10	4	7	6	14	0	48
2825 509 6312	Air Gland	6	10	5	8	6	6	0	41
2825 509 6314	Governor Valve	6	2	0	2	0	0	0	10
2825 509 6320	Gear - Wm Whl	0	0	0	1	0	0	0	1
2825 509 6322	Baffle Oil	7	2	0	2	1	0	7	19
2825 509 6328	Bushing - VL BO	2	0	0	0	0	0	0	2
2825 509 6329	Stem - VL	3	0	0	0	0	0	0	3
2825 509 6330	Seat - VL Gov	4	0	0	0	0	0	0	4
2825 509 6332	Bearing Jo	4	2	5	4	1	1	1	18
2825 509 6337	Diaphragm - STM TUR	1	0	0	1	0	0	0	2
2825 509 6338	Valve - Cap	0	0	0	1	0	0	0	1
2825 509 6346	Shroud - Retainer	1	0	0	0	0	0	0	1
2825 526 9898	Spring - HLCPS	0	78	0	0	16	48	0	142
2825 527 0654	Spring - HLCPS	0	16	0	8	16	48	0	88
2825 528 5804	Piston - Ring	1	0	0	1	0	0	0	2
2857 659 9820	Nozzle Black - Turbine	1	0	0	0	0	0	0	1
3010 529 0030	Coupling	2	0	0	1	0	0	0	3
3110 144 8534	Bearing	0	1	0	0	0	0	0	1
3110 144 8669	Bearing	0	2	0	0	1	0	0	3
3110 156 5059	Bearing, B ANN	0	2	0	2	0	0	0	4
3110 156 5490	Bearing, B ANN	1	1	0	0	1	0	0	3
3120 541 9429	Bearing - SLV	0	1	0	0	1	0	0	2
4320 318 7244	Bushing - AY	0	1	2	0	0	0	0	3
4320 544 6940	Ring Assembly	0	1	6	2	0	0	0	9
4710 277 4656	----	0	0	20	0	0	0	0	20
4710 542 4323	Tube	50	0	120	0	0	0	0	170
4710 542 4326	----	0	0	0	0	0	0	24	24
4720 289 3422	Spacer	3	0	0	0	0	0	0	3
4730 222 1860	----	0	2	0	0	0	0	0	2
4730 289 8133	----	0	2	4	0	0	0	0	6
4730 407 1069	Flange	0	0	104	0	0	0	0	104
4730 759 9825	Flange	0	0	120	0	0	0	0	120
4820 346 1769	----	0	3	2	2	3	0	1	11
4820 542 2843	----	0	0	0	6	0	0	0	6
4820 824 8650	----	0	60	0	0	0	0	6	66
5306 825 4422	Bolt	0	25	0	0	0	0	0	25
5310 483 6423	HSG Line	1	0	0	0	0	0	0	1
5330 178 9792	Gasket	0	0	0	0	0	0	5	5
5330 197 8494	Packing 3/8	0	0	0	120	0	0	106	236
5330 197 8525	----	0	150	0	0	0	0	0	150
5330 197 8538	Packing 1/2	0	25	0	0	0	0	0	25
5330 197 8539	Packing	0	44	215	1	0	38	0	298
5330 197 9653	----	0	70	0	0	0	0	0	70
5330 197 9654	----	0	302	75	0	0	108	0	485
5330 197 9655	----	0	50	0	0	0	0	0	50
5330 197 9656	----	0	50	0	50	4	0	0	104
5330 197 9657	----	0	18	100	0	0	0	0	118
5330 222 2566	----	0	10	0	0	0	0	0	10
5330 239 3737	Gasket	0	1	0	0	0	0	0	1
5330 371 8095	----	0	300	0	0	0	0	0	300
5330 543 6082	----	0	34	75	0	0	125	0	234
5330 543 6085	----	0	34	0	0	0	0	0	34
5330 599 1585	Packing - Pre FMD	0	0	4	1	0	0	0	5
5330 599 9545	----	0	50	0	0	0	0	0	50
5330 599 9546	----	0	50	0	0	0	58	0	108
5330 599 9547	----	0	50	0	0	0	0	0	50
5330 599 9548	----	0	17	0	0	0	20	0	37
5330 599 9549	----	0	50	0	0	0	0	0	50
5330 599 9550	----	0	13	0	0	0	35	0	48
5330 599 9551	----	0	50	0	0	0	0	0	50
5330 599 9552	----	0	50	0	0	0	0	100	150
5330 641 7277	Gasket	0	0	0	1	0	0	8	9
5330 641 7278	Gasket	0	1	0	1	0	0	0	2
5340 726 7939	Shim	3	2	0	5	0	0	0	10
5365 805 9529	Ring - Ret	0	0	0	1	0	0	0	1
6685 244 1830	Pressure Gauge	17	11	0	5	1	6	30	70
6685 246 2364	Gauge	3	0	0	1	2	0	0	6
6685 246 2365	Gauge	5	0	9	6	2	6	0	28
6685 248 1654	----	0	0	3	0	0	0	0	3
6685 248 1655	----	2	0	16	0	5	0	0	23
6685 248 1656	Gauge	14	3	15	0	1	0	1	34
6685 248 1677	----	0	0	2	1	0	0	0	3
6685 248 1691	----	0	0	2	0	0	0	0	2
6685 248 1694	Gauge	0	2	12	3	0	0	0	17
6685 252 3018	----	0	0	12	4	0	1	0	17
6685 252 3023	Gauge	0	0	6	0	0	0	0	6
6685 527 6312	Gauge	0	0	17	0	0	0	0	17
6685 529 5971	----	0	0	0	0	0	3	0	3
6685 782 5243	----	3	0	0	0	0	0	0	3
6685 782 5247	Thermo	3	45	0	14	0	8	0	70
6685 782 5249	Thermo	5	10	0	6	0	8	0	29
6685 785 251	----	0	2	0	1	0	8	0	11
6685 803 8628	----	0	4	5	0	4	0	0	13
6340 618 8107	Window	0	0	4	0	0	0	0	4
9510 268 9551	----	0	1	0	0	0	0	0	1
951 0268 9552	----	0	1	0	0	0	0	0	1

APPENDIX B

TREND CURVES AND SUMMARIES FOR CORRECTIVE-MAINTENANCE EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR

This appendix presents trend curves of corrective-maintenance events and maintenance man-hours per operating hour for the MFP turbines for the six-year period July 1966 through June 1972; the curves were prepared by using the procedure presented in Special Report No. 1. A separate plot is provided for each of the seven ships. The average for all ships is also shown on each plot.

The following paragraphs summarize the plots.

DDG-4, Figure B-1

No shipyard work on MFP turbines was reported during the entire period. The increase in event rate from late 1968 through early 1969 was the result of actions on gages and thermometers. The increased man-hour rate in 1971 was the result of major repairs to MFP Turbine 2A. The trends do not suggest the need for work during ROH.

DDG-5, Figure B-2

No data are available on possible shipyard work during the 1966 ROH or the 1968 RAV. No shipyard work was reported for the 1970 ROH or subsequent RAVs. The high man-hour rate in 1967 was the result of repairs to air and steam glands on four MFP turbines. The increase in event rate in 1970 was the result of low-man-hour events on all MFP turbines during ROH. The trend curves indicate that it is necessary to replace air and steam glands during ROH.

DDG-6, Figure B-3

No shipyard work was reported for the 1966 ROH. During the 1969-70 ROH, the shipyard overhauled two MFP turbines. The high event and man-hour rates in 1970 resulted from gland and bearing work on four MFP turbines, including one that had been overhauled during the last ROH. The trend curves indicate the need for additional work during ROH.

DDG-9, Figure B-4

No shipyard work was reported for the 1967 and 1970 ROHs and 1968 RAVs. One turbine was overhauled during the early 1969 RAV. No data are available

on possible shipyard work during the late 1969 and 1970 RAVs. The high manhour rate shortly after the 1967 ROH resulted from bearing and governor work on two MFP turbines. The trend curves indicate that work should have been performed on MFP turbines during the 1967 ROH.

<u>DDG-14, Figure B-5</u>

No shipyard work was reported during the 1967 ROH and RAVs in 1967 and 1969-70. During the 1971 ROH, alteration work was reported on all MFP turbines. The trends for ship's force work remained insignificant throughout the period and do not indicate the need for shipyard work.

<u>DDG-23, Figure B-6</u>

No shipyard work was reported for the 1967 ROH. The shipyard reported major work on MFP turbines during the 1971 ROH. The trends for ship's force work remained insignificant throughout the period and do not indicate the need for shipyard work.

<u>DDG-24, Figure B-7</u>

No data are available on possible shipyard work during the 1966 RAV and 1967 ROH. No shipyard work was reported during the ROH or RAV in 1971. The ship's force reported major work on three MFP turbines just prior to the 1967 ROH. The trends between ROHs do not indicate the need for work during ROH.

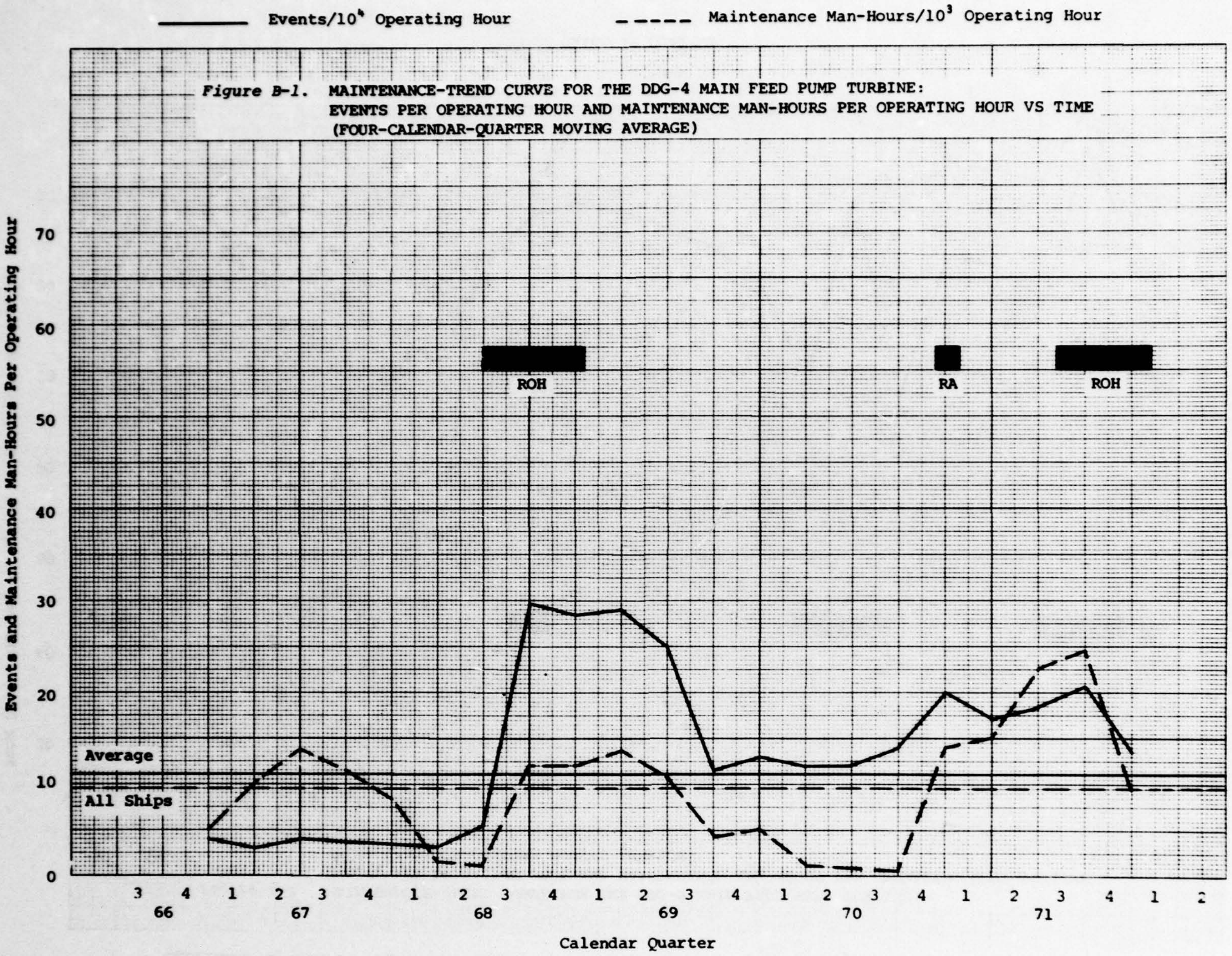

Figure B-1. MAINTENANCE-TREND CURVE FOR THE DDG-4 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

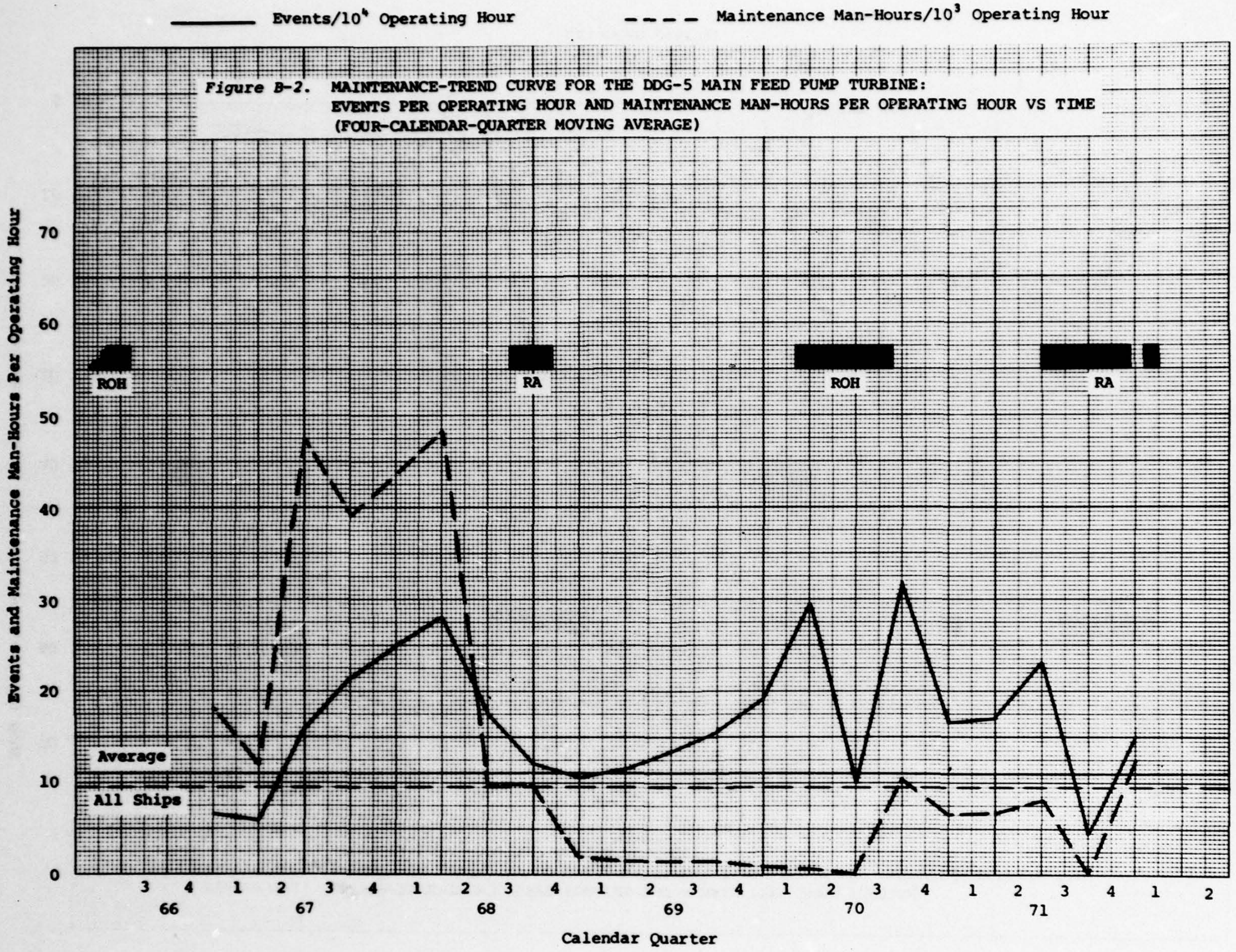
Figure B-2. MAINTENANCE-TREND CURVE FOR THE DDG-5 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

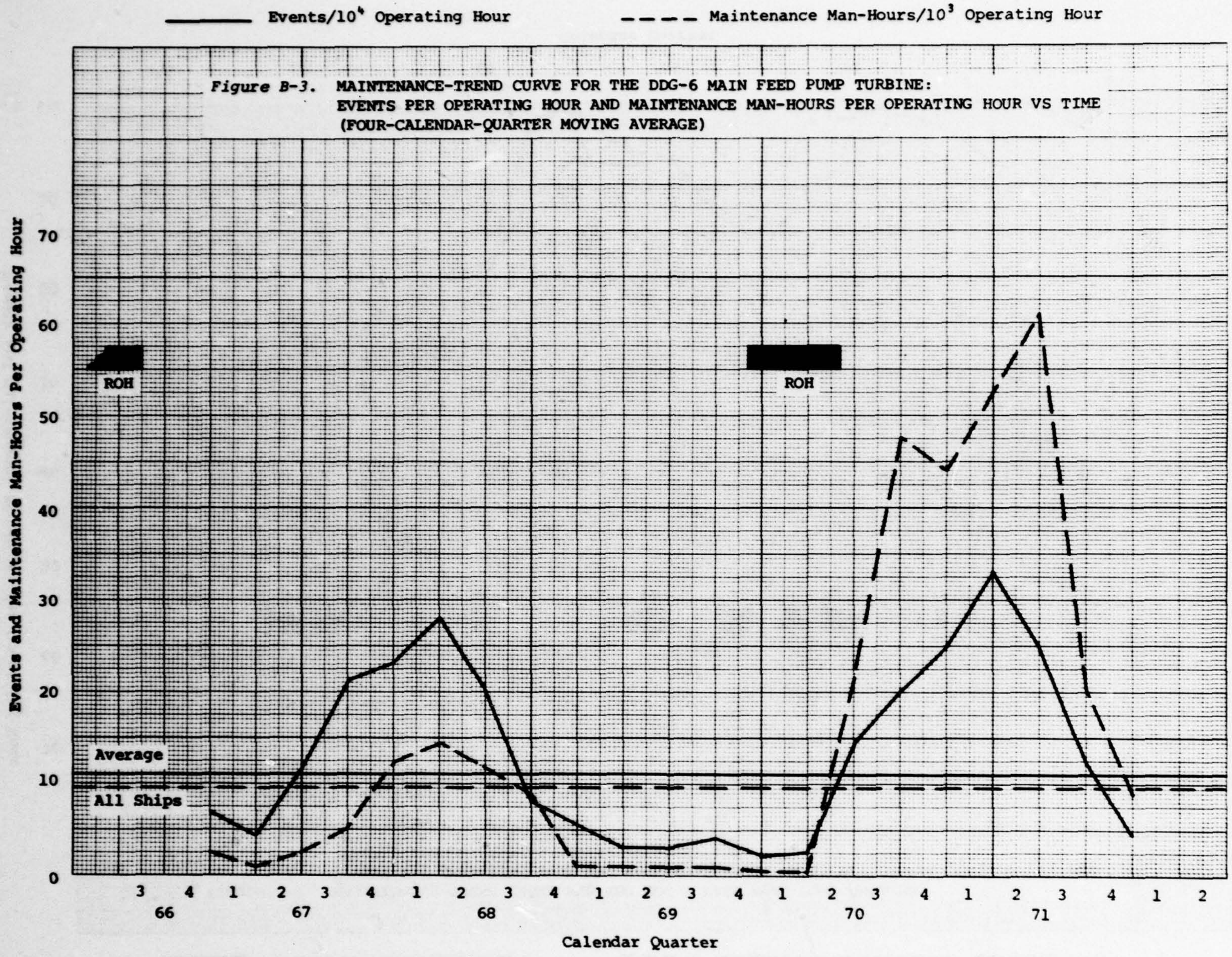

Figure B-3. MAINTENANCE-TREND CURVE FOR THE DDG-6 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

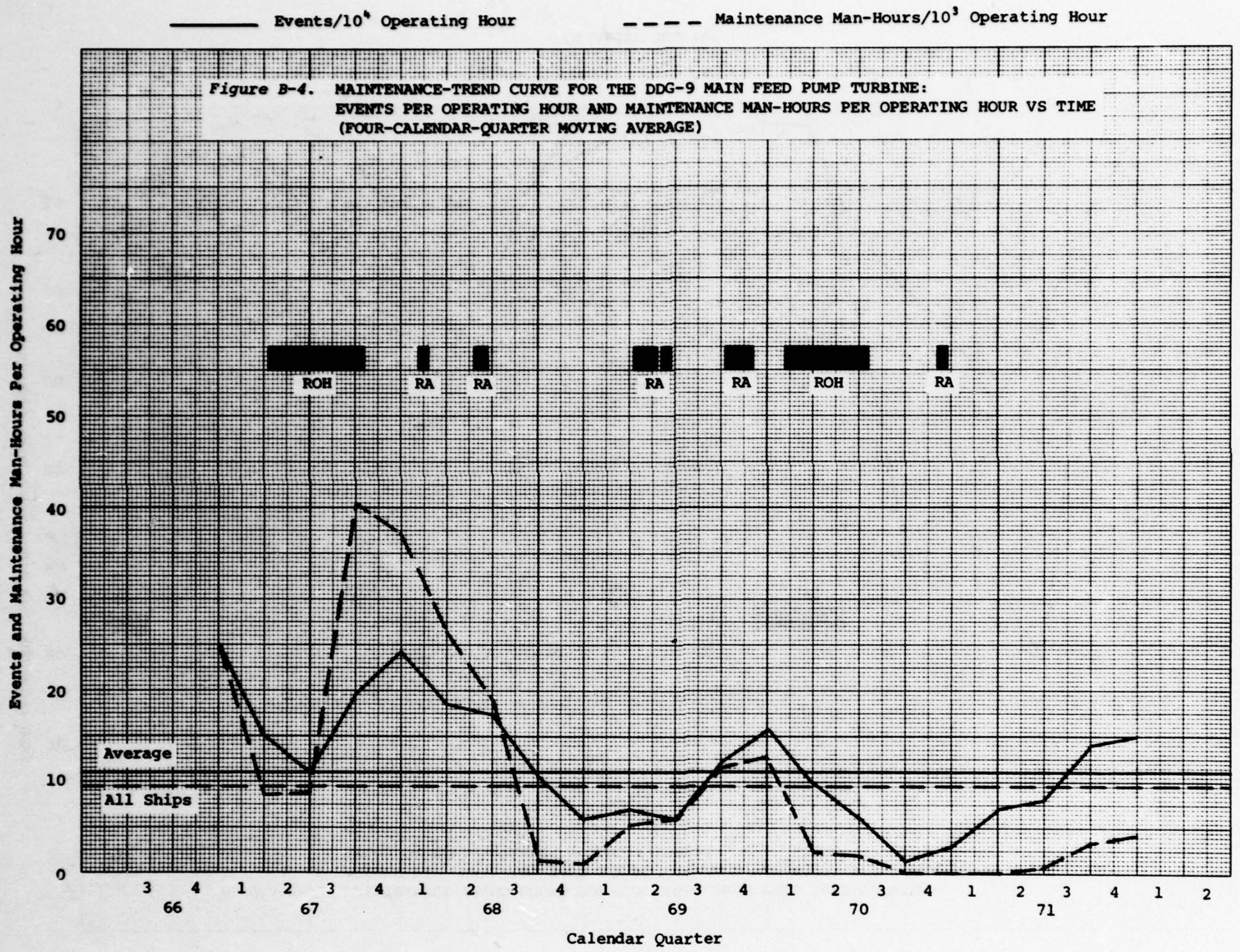

Figure B-4. MAINTENANCE-TREND CURVE FOR THE DDG-9 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

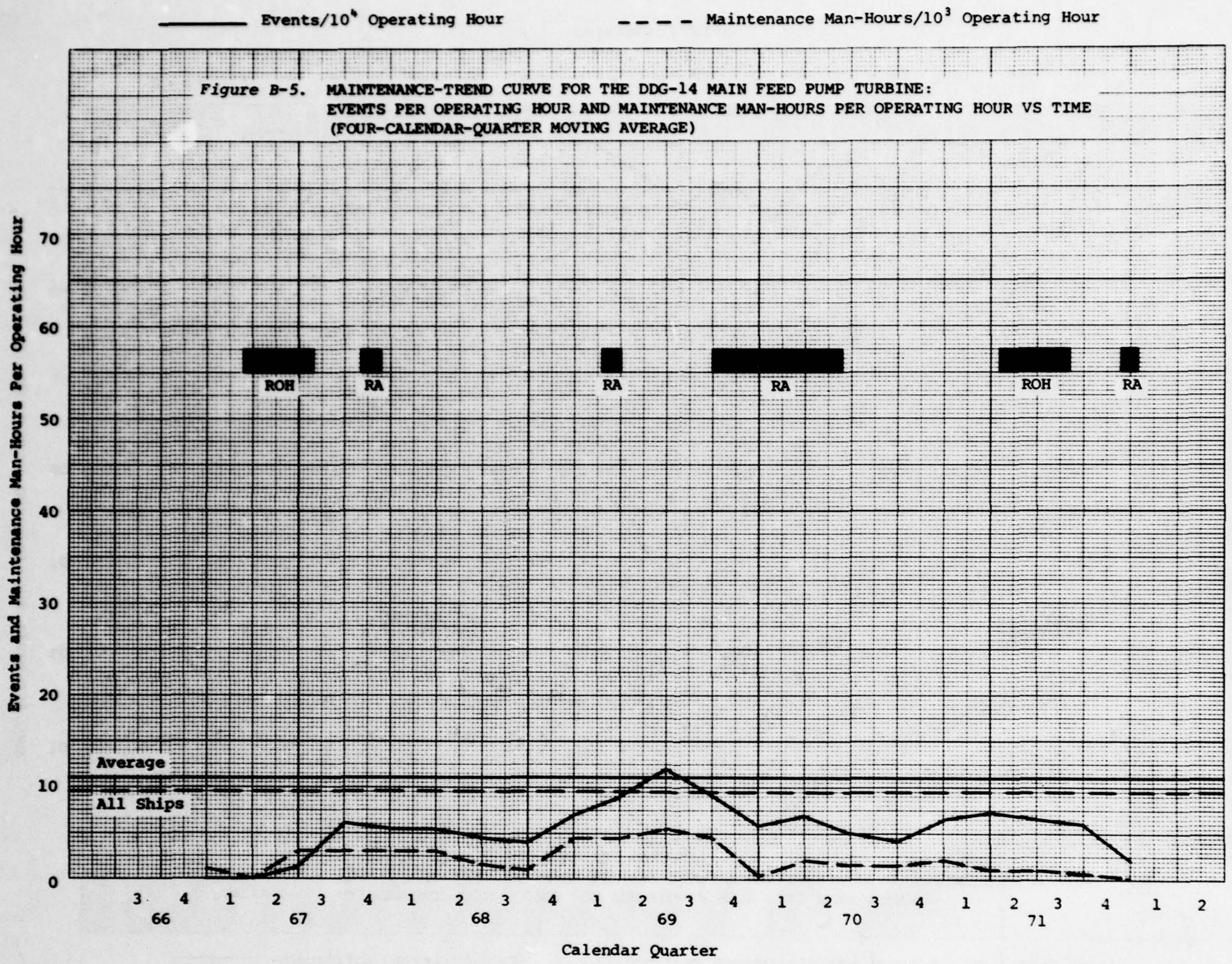

Figure B-5. MAINTENANCE-TREND CURVE FOR THE DDG-14 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

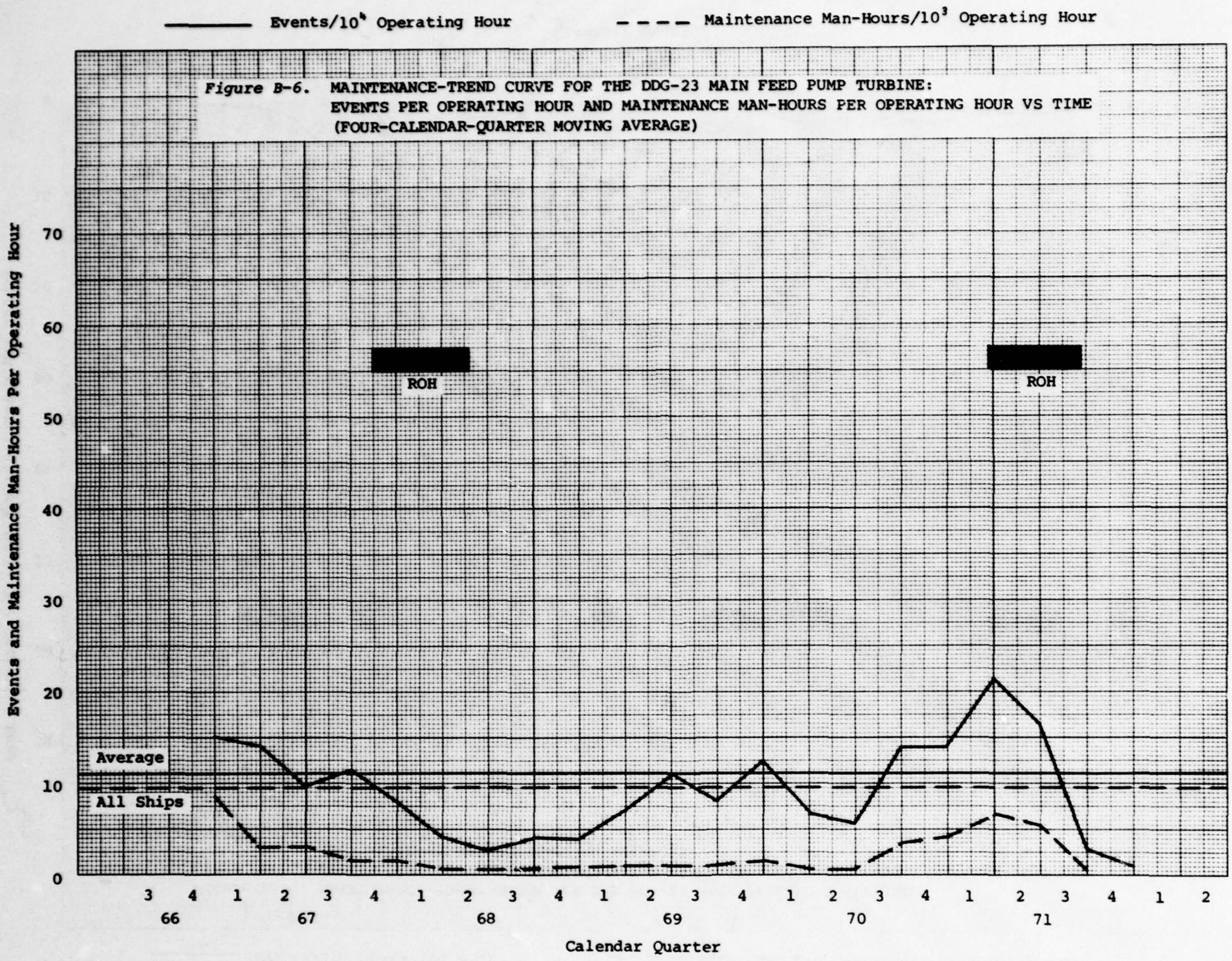

Figure B-6. MAINTENANCE-TREND CURVE FOR THE DDG-23 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)

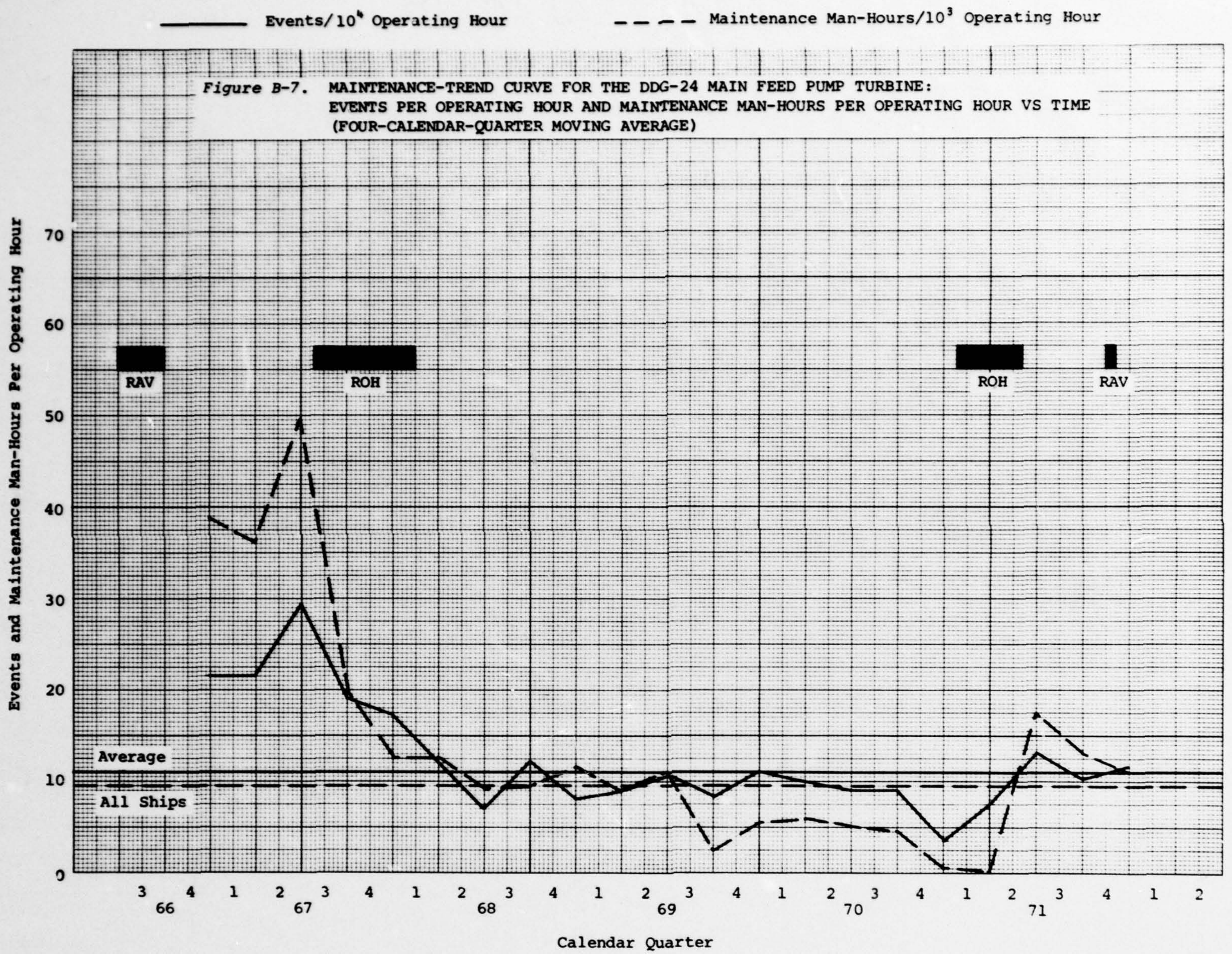

Figure B-7. MAINTENANCE-TREND CURVE FOR THE DDG-24 MAIN FEED PUMP TURBINE: EVENTS PER OPERATING HOUR AND MAINTENANCE MAN-HOURS PER OPERATING HOUR VS TIME (FOUR-CALENDAR-QUARTER MOVING AVERAGE)